CEBAF PROPOSAL COVER SHEET

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CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

and received on or before OCTOBER 30, 1989

A. TITLE: Inclusive Scattering from Nuclei @ $x > 1$ and High Q^2

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C. THIS PROPOSAL IS BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT

☒ YES
☐ NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

A Proposal to study Deep Inelastic Scattering from Nuclei at $x > 1$ and High Q^2

D. ATTACH A SEPARATE PAGE LISTING ALL COLLABORATION MEMBERS AND THEIR INSTITUTIONS

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Letter Received 10-30-89

Log Number Assigned PR-89-008

By KES

contact: Filippone

CEBAF PROPOSAL

Inclusive Scattering from Nuclei at $x > 1$ and high Q^2

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(11/89)

Abstract

We propose an inclusive electron-nucleus scattering experiment in the domain of large x and Q^2, to study the A-dependence of the nuclear structure functions. Such studies can provide important constraints on the components of the nuclear wave function at large momentum and removal energy, and on non-nucleonic degrees of freedom.

I. Introduction

Inclusive electron-nucleus scattering provides us with the most general response of a nuclear system to the electromagnetic probe. The inclusive response functions also provide important input for the understanding of exclusive experiments which look at individual channels in the final state.

In the past, inclusive scattering has been studied in great detail in the region of the quasielastic peak (Bjorken scaling variable $x \simeq 1$); the main issues have been the excess of transverse strength in the dip region, and the lack of longitudinal strength in the region of the peak. Inclusive scattering has also been studied extensively at very large inelasticities ($x < 1$); the main issues have been the determination of quark distribution functions in the nucleon, and their modification due to the nuclear environment [1,2,3] Inclusive scattering at 'low' energy loss ($x > 1$) has been studied to a lesser degree, with data available only for a restricted set of Q^2, x-values[4,5]; the main issues here have been the observation of y-scaling and the related study of high momentum components in the nucleus.

The limited amount of data available for $x > 1$ is largely due to the low cross sections in this region. The high luminosities expected from CEBAF should allow a significant extension in the region of x and Q^2 covered. It is the aim of the proposed experiment to provide a more complete picture of the inclusive electromagnetic response.

II. Physics Motivation

In the region of $x \gtrsim 1$ and moderate Q^2, the dominant scattering process is one of quasielastic electron-nucleon scattering. In this region the data exhibit scaling[6,7] in the variable y. The scaling function $F(y)$ provides information on the nucleon momentum distribution. This information is of particular interest as $| y |$ increases ($x \gg 1$); in the low energy-loss wing of the quasielastic peak the components of large initial-nucleon momentum and large removal energy play an important role. This region of kinematics thus is particularly interesting in studies of the role of nucleon-nucleon correlations[8].

In the past, studies of this region have not been able to answer conclusively questions concerning the convergence of $F(y, Q^2)$ in the $Q^2 \rightarrow \infty$ limit, mainly due to the lack of adequate, precise data. This convergence is of interest both for an understanding of the effects of final state interactions [9,10] (leading to an expected 1/Q-convergence), and a measure of the effects of large removal energies [11].

In the region of very large x and Q^2, the fall-off of the nucleon form factors with Q^2 leads to a decrease in the contribution from quasielastic processes. Deep inelastic scattering from the quark constituents of the nucleus is expected to eventually dominate [12], as it does for $x < 1$. An interesting relation between the quasielastic and deep inelastic response has been discussed recently[13], where there are indications of a scaling behavior of the existing data in terms of the Nachtmann variable (a modification of the x-variable made to account for target-mass effects)[14].

Studies of this region at very large x, Q^2 are also of particular interest in connection with the EMC effect. Values of $x = 2 - 3$ correspond to coherent scattering from a system that has $2 - 3$ times the nucleon mass. Nuclear effects, such as 6 quark components of the wave function, have been predicted to lead to significant effects [15] on the inclusive response at very large x, Q^2. As discussed above, little information is available in this kinematic region at present, due to the small cross sections coupled with the low beam intensity and solid angle available in the previous experiments at SLAC.

III. New Possibilities at CEBAF

As compared to the past experiments, performed at SLAC using the 8 GeV spectrometer, CEBAF offers a significant improvement:

1. The solid angle of the HMS is a factor of 10 larger than for the 8 GeV spectrometer,
2. The spectrometer momentum acceptance is larger by a factor of 1.5,
3. The beam intensity (100 μA) is a factor of 10 larger than that available at NPAS.

Overall, we can expect an increase in sensitivity of about a factor of 150 compared to previous experiments. This will allow us to greatly extend the region of x,Q^2 covered, and move into the region where deep inelastic scattering should dominate even at $x > 1$. At the same time, the improved data in the y-scaling region will permit more detailed studies of the convergence properties of $F(y)$. The kinematic range accessible is shown in Figs. 1 and 2, where the range of scaling variables x and y is compared with the previous experiments at SLAC.

IV. Proposed Experiment

In order to estimate counting rates and running times we need a model for the cross section. We will take the previous data [5] from SLAC at lower Q^2 as a guide and attempt an extrapolation. A recent analysis [13] of that data has shown an intriguing scaling of the structure function when analyzed with the Nachtman scaling variable $\xi = 2x/[1+(1+4M^2x^2/Q^2)^{1/2}]$. This variable has been shown to be the correct variable in which to study scaling violations of the deep inelastic response at finite Q^2 and accounts for the finite target mass M_N. We will take the highest Q^2 results [corresponding to $Q^2 \sim 3$ (GeV/c)^2] and assume convergence (ie. no further dependence on Q^2) and extrapolate to the Q^2 of interest. We will assume 100 μA of beam current, a 6 % Fe target, a spectrometer solid angle of 7 msr, a $\Delta p/p$ bite of 10 %, and a fixed x bin of 0.05. Note however that if the structure function departs significantly from the above model the accessible range in x would be modified.

Time estimates are shown in Table I, at incident beam energies of 4 and 6 GeV. Estimates are made for two extreme kinematic points, one at a small forward angle and one at a large angle. The measurements would actually be performed at several angles to cover the full kinematic range. In addition several nuclear targets would be studied (eg.^{12}C, ^{56}Fe, and ^{197}Au) in order to probe the A-dependence of the structure functions. For the forward angle measurements, which reach the largest values of x, a spectrometer with maximum momentum > 4 GeV/c is important for the 6 GeV beam energies. As can be seen from the running times, $Q^2 \geq 11$ (GeV/c)^2 and $x > 2-3$ can be achieved.

Backgrounds can be controlled with an adequate detector package. Parameterizations of previous pion photo- and electro-production indicate that π/e ratios may reach ~ 200, but a threshold Cerenkov detector and electromagnetic shower counter can provide sufficient particle indentification to reduce the uncertainties due to pion subtraction to $< 2-3\%$. This is confirmed by our previous experience with the 8 GeV spectrometer at SLAC.

Thus an inclusive scattering experiment exploring the deep inelastic and quasielastic response of nuclei at large x and large Q^2 appears to be easily within reach. Clearly this experiment can be run shortly after turn-on as a 4 GeV beam covers a significant fraction of the kinematic range (see Figs. 1 - 2), especially the very important large $|y|$ region. Such an experiment can provide important physics results early, as well as set the stage for further studies of this kinematic range with coincidence experiments (ie. Color Transparency studies at $x \geq 1$).

V. Resources Required

This experiment requires a high momentum spectrometer ($p_{max} > 4$ GeV/c) and a detector package configured for electron detection with good hadron/electron discrimination such as provided by the combination of a gas Cerenkov detector and a total absorption shower counter. A momentum resolution of 10-20 MeV/c is sufficient. Solid targets capable of withstanding currents on the order of 100 μA (achieved via beam position rastering and direct cooling of the target) are also required. A low power hydrogen target is also required as part of the spectrometer and detector calibration. As the experiment is single arm with a conventional detector package, the data acquisition and analysis can rely heavily on previously developed software (and previous experience of the collaboration with similar hardware) allowing a rapid physics answer from the experiment.

VI. Commitment of Collaboration

Several members of this collaboration are members of the Hall C Steering committee which is investigating experimental equipment for this Hall. Some members have been involved in the design of the detector package for the high momentum spectrometer which would be used for this experiment and are interested in constructing some of the elements.

VII. Beamtime Request

In order to study the kimematic region outlined in Figs. 1, 2 for three target nuclei, we request a total of 1000 hrs. of beamtime. This includes 100 hrs. of lower current running (1 - 10 μA) for calibration and checkout.

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Table I

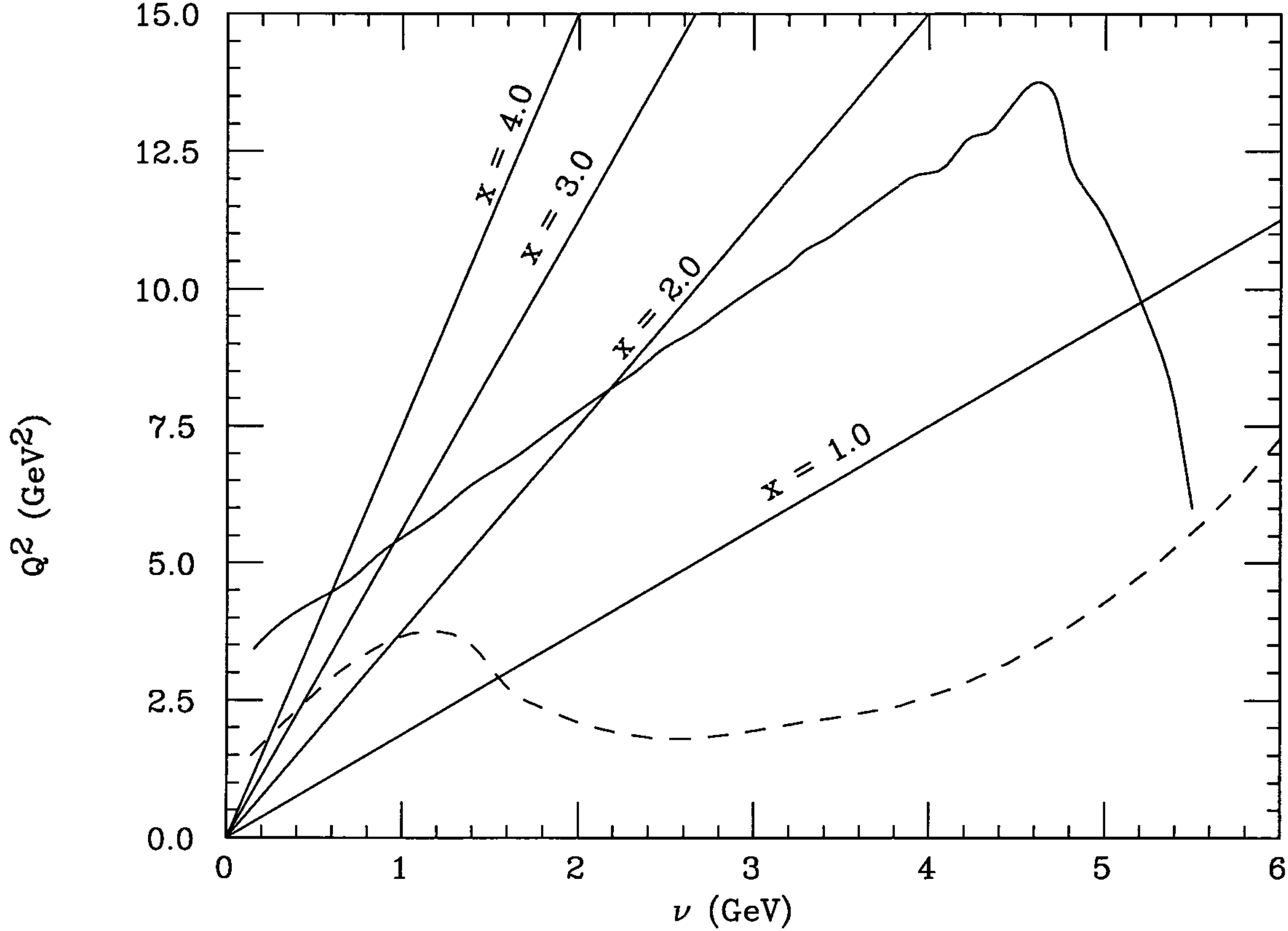
Running times and kinematics for two extreme kinematic points for both a 4 GeV and 6 GeV beam energy. Rates are for 100 μA DC beam current, a 6% Fe target, 7 msr solid angle, and a 10% $\Delta p/p$ momentum bite. Running times are for a fixed dx bin of 0.05. The assumed uncertainty for a bin in x is 10% for the small angle and 25% for the large angle. The total running time for this target is $\simeq$ 300 hrs.

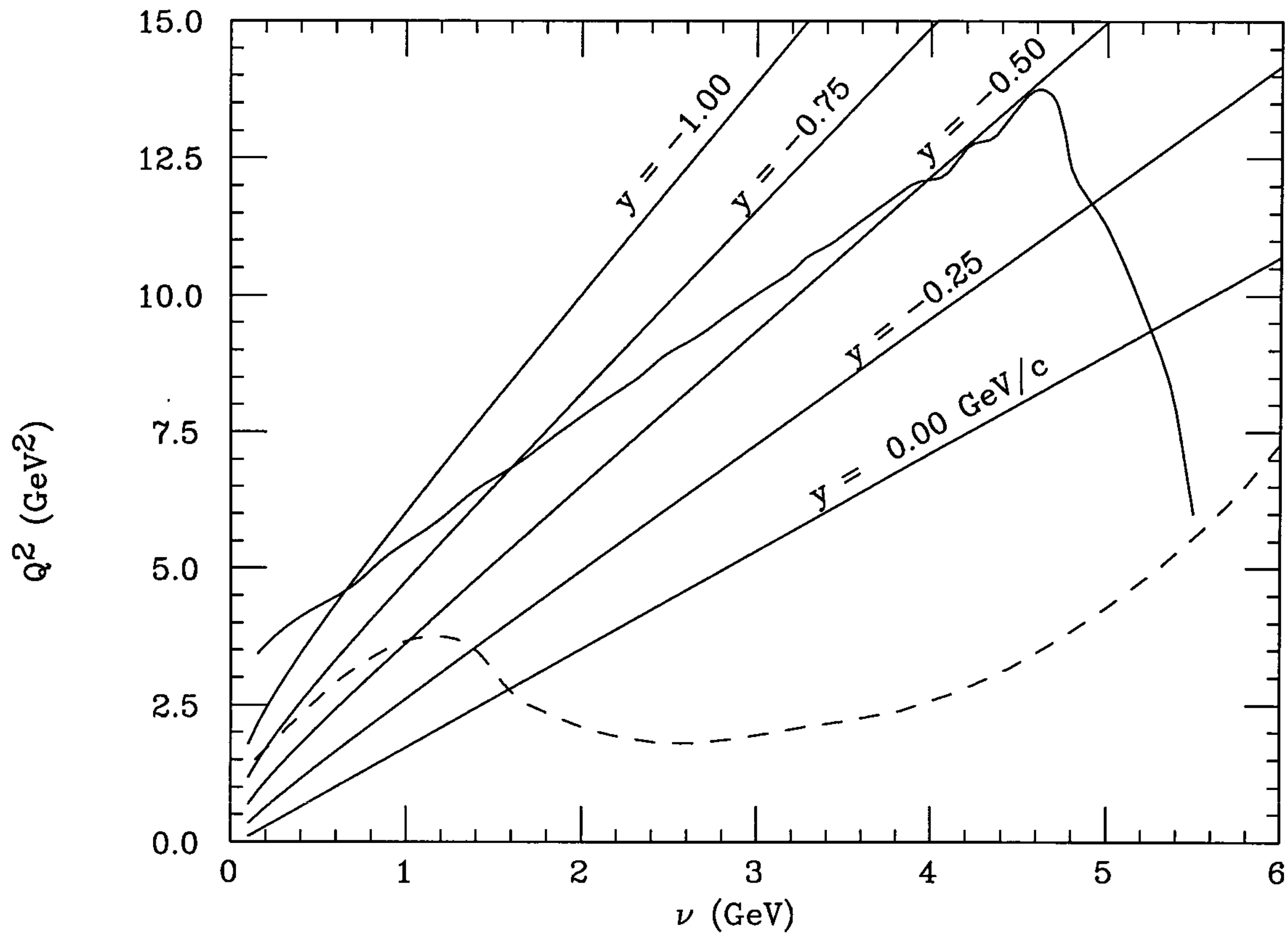
E (GeV)	θ (deg.)	E′ (GeV)	x	Q^2 (GeV^2)	σ_{tot} (nb/sr/MeV)	time/x (hr)
4.00	20.0	2.627	0.49	1.27	2.64E + 00	2.8E − 06
		2.896	0.67	1.40	1.53E + 00	0.8E − 05
		3.193	1.02	1.54	6.82E − 01	3.2E − 05
		3.520	1.88	1.70	7.51E − 02	0.8E − 03
		3.881	8.36	1.87	6.58E − 04	1.5E + 00
4.00	60.0	0.670	0.43	2.68	5.02E − 02	3.4E − 05
		0.739	0.48	2.95	3.47E − 02	5.2E − 05
		0.814	0.54	3.26	2.36E − 02	0.8E − 04
		0.898	0.62	3.59	1.57E − 02	1.3E − 04
		0.990	0.70	3.96	9.85E − 03	2.1E − 04
		1.091	0.80	4.37	5.53E − 03	4.0E − 04
		1.203	0.92	4.81	2.51E − 03	1.0E − 03
		1.327	1.06	5.31	7.75E − 04	3.4E − 03
		1.463	1.23	5.85	1.14E − 04	2.6E − 02
		1.613	1.44	6.45	1.17E − 05	2.9E − 01
		1.778	1.70	7.11	8.52E − 07	4.5E + 00
		1.960	2.05	7.84	4.11E − 08	1.1E + 02
6.00	15.0	4.440	0.62	1.82	1.62E + 00	4.4E − 06
		4.884	0.95	2.00	6.21E − 01	2.4E − 06
		5.372	1.86	2.20	2.04E − 02	2.2E − 03
		5.910	14.24	2.42	2.91E − 05	0.8E + 02
6.00	70.0	0.652	0.51	5.15	7.21E − 03	2.7E − 04
		0.717	0.57	5.66	4.89E − 03	4.1E − 04
		0.789	0.64	6.23	3.20E − 03	6.4E − 04
		0.868	0.71	6.85	1.97E − 03	1.1E − 03
		0.955	0.80	7.54	1.07E − 03	2.0E − 03
		1.050	0.89	8.29	4.81E − 04	4.7E − 03
		1.155	1.00	9.12	1.54E − 04	1.5E − 02
		1.271	1.13	10.03	2.69E − 05	0.9E − 01
		1.398	1.28	11.04	3.68E − 06	0.7E + 00
		1.538	1.45	12.14	3.94E − 07	0.7E + 01
		1.692	1.65	13.36	3.18E − 08	1.0E + 02

Figure Captions

Fig. 1. The kinematic range in Q^2 and ν are shown for several values of the Bjorken x variable. The region below the dashed curved has been studied in previous experiments at SLAC. The region below the solid curve and above the dashed curve is the range accessible with a 6 GeV beam at CEBAF. For a 4 GeV beam, the accessible range is similar except for a cutoff near $\nu = 3$ GeV.

Fig. 2. The kinematic range in Q^2 and ν are shown for several values of the y-scaling variable. The region below the dashed curved has been studied in previous experiments at SLAC. The region below the solid curve and above the dashed curve is the range accessible with a 6 GeV beam at CEBAF. For a 4 GeV beam, the accessible range is similar except for a cutoff near $\nu = 3$ GeV.


x = 4.0
x = 3.0
x = 2.0
x = 1.0
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1
2
3
4
5
6
ν (GeV)
Q² (GeV²)



y = −1.00
y = −0.75
y = −0.50
y = −0.25
y = 0.00 GeV/c
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1
2
3
4
5
6
Q^2 (GeV^2)
ν (GeV)

Continuous Electron Beam Accelerator Facility

12000 Jefferson Avenue
Newport News, Virginia 23606
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Proposal Number: PR-89-008

Proposal Title: Inclusive Scattering from Nuclei at x>1 and High Q^2

Spokespersons/Contact Persons: D. Day, B. Filippone

Proposal Status at CEBAF:

Approval for 8 days to be run when 4 GeV electrons are available.

Dirk Walecka

John Dirk Walecka
Scientific Director